bulb for a distance of half an inch or more, so as to cool this part of the thermometer as well as the bulb. It must be wrapped close and tight for not more than one and a half turns around the bulb. The free end below the bulb must be tied in closely and left projecting for an eighth of an inch or more. The psychrometric formula and tables are computed for this sort of covering. Failure to wash out the sizing in new muslin or a wrinkling of the covering so that it fails to fit the bulb closely, is likely to give erroneous readings.

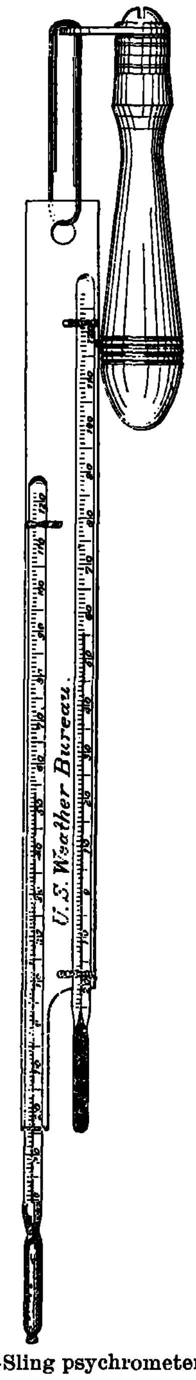


FIG. 20.—Sling psychrometer (Marvin).

METEOROLOGICAL OBSERVATORY AT TENERIFFE.

We are pleased to announce that the Spanish authorities are cordially cooperating with the International Aeronautical Commission and the German Government in supporting the high-level meteorological observatory on Teneriffe. It has been decided to open the doors of the observatory to qualified investigators of all nationalities.—*C. A., jr.*

THE RELATIONS OF THE INVERSIONS IN THE VERTICAL GRADIENT OF TEMPERATURE IN THE ATMOSPHERE TO AREAS OF HEAT AND COLD.

By HENRY HELM CLAYTON. Dated Readville, Mass., March 2, 1909.

When recording instruments are sent aloft on kites or balloons they show that, at least in the lower air, the temperature usually falls with increasing height above the ground; but there are belts or regions where the temperature rises with increasing height above the ground. These regions of rising temperature have received the name of inverted gradients. The belts of inverted gradient play an important part in atmospheric phenomena. They separate the air into strata with marked contrasts in humidity, wind velocity, and cloud formation. Usually the maximum of humidity and the clouds are immediately below the inverted gradient, but sometimes this condition is reversed. Usually there is a maximum of wind velocity within or very near each inverted gradient which occurs within 4,000 meters of the earth's surface. There are undoubtedly many other important relations to meteorological phenomena which remain to be disclosed.

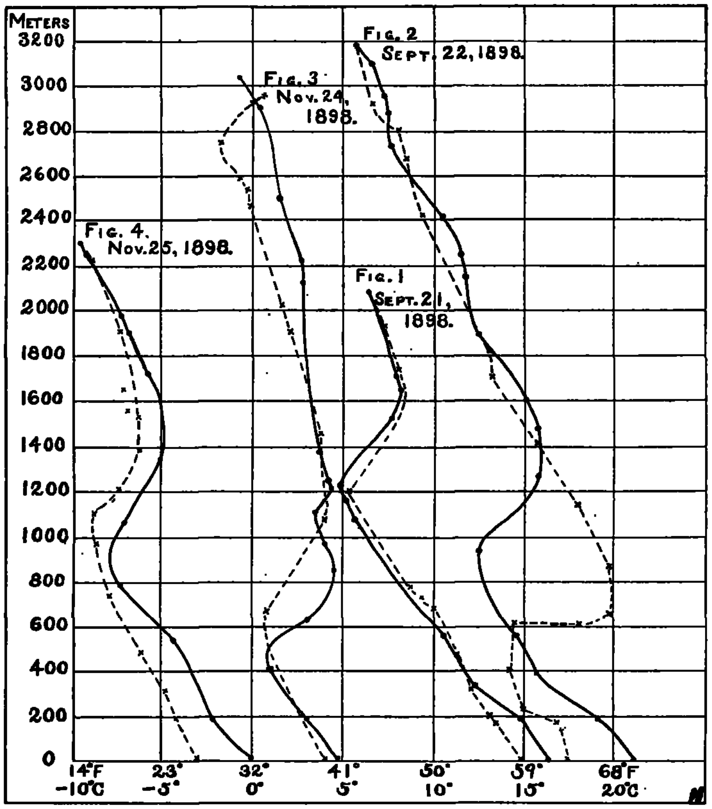
Studies of these inversions have been made by Rykachev,[1] Assmann,[2] A. J. Henry,[3] and myself.[4] The conclusion which I reached[4] from a study of the data at Blue Hill was that "*the belts of inverted gradient reached their greatest distance from the ground about the time of minimum temperature, and were nearest the ground about the time of maximum temperature.*"

In a recent study of the records obtained with kites and sounding balloons on the expedition of M. Teisserenc de Bort and Professor Rotch in the trade wind region, I found that the inverted strata dipped from about 40° north to the heat equator and then rose again in southern latitudes. Hence, I am led to conclude that it is a general law for the inverted gradients of temperature to incline upward from regions of warmth toward regions of cold, and vice versa.

The reason of this rule is probably because air flowing from regions of cold towards regions of warmth has a descending component of motion and the inclination of the inverted gradient indicates the angle of descent. On the other hand air moving from regions of warmth toward regions of cold is ascending and the inclination of the inverted gradient indicates the rate of ascent. But ascending air is expanding and cooling so that in time the moisture in such inclined ascending currents becomes condensed into cloud and in this way is undoubtedly to be explained the presence of stratiform clouds such as nimbus, alto-stratus, cirro-stratus, which are found immediately beneath these inverted gradients.

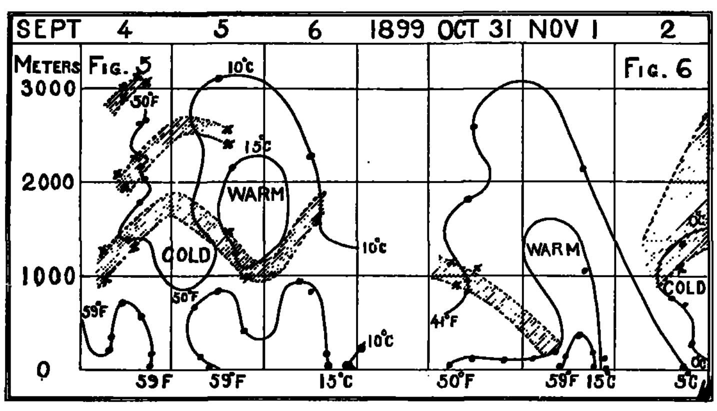
How the inverted gradients dip downward as the temperature of the air in which they occur rises and how they ascend as the temperature falls is here illustrated by some examples taken from my discussion of the observations at Blue Hill in Bulletins No. 1, 1899, and No. 1, 1900, of the Blue Hill Meteorological Observatory. Figs. 1 and 2, in the accompanying diagrams, show plots of the temperatures recorded at different heights on September 21 and 22, 1898, when the temperature was rising. Dots connected by a continuous line show the points where the temperature was read from the records made during the ascent of the kite and crosses connected by a broken line show the temperatures during the descent of the kite. It is seen from fig. 1 that the inverted gradient was between 1,200 and 1,700 meters during the ascent on September 21. By the morning of September 22, see fig. 2, the temperature had risen some 10° to 15° F., and the inverted gradient had descended several hundred meters. During the descent of the kites on the afternoon of the same day the inverted gradient had descended to within 650 meters of sea-level.

[1] Meteorol. Zeitschr., Hann-Band., p. 174.
[2] R. Assmann, Beiträge z. Physik d. f. Atmosph., 1:39.
[3] Bul. Mount Weather Observ., 1908, 1, pt. 3:143.
[4] Bul. Blue Hill Meteor. Obs., 1900, No. 1:7, 11.



FIGS. 1, 2, 3, 4.—Vertical gradients of temperature at Blue Hill, Mass., in September and November, 1898.

Figures 3 and 4 show plots of the temperature with relation to height on November 24, 25, 1898, days when the temperature was falling. It is seen from the figures that the inverted gradient was lowest during the ascent of the kites on the morning of November 24, when it was between 500 and 700 meters. At later observations it was found successively higher until the descent of the kites on the afternoon of November 25, when the inversion was between 1,100 and 1,500 meters. The temperature in the meantime had fallen about 10 degrees at the ground and 15 degrees at 1,000 meters.



FIGS. 5, 6.—Vertical distribution of temperatures at Blue Hill, Mass., during successive days in September, October, and November, 1899.

When the temperature observations are plotted in relation to time and height, as in figs. 5, 6, 7, and 8, and the inverted gradients are indicated by shaded areas, these are seen to form belts which rise and fall inversely to the isothermal lines, so that they are highest in cool areas and lowest in warm areas. The great upper air inversion at above 10 kilometers apparently conforms to the same law, rising and falling inversely with the temperature in the upper air, but the proof of this is not yet conclusive. In these cuts dots and crosses indicate some of the points where observations were obtained.

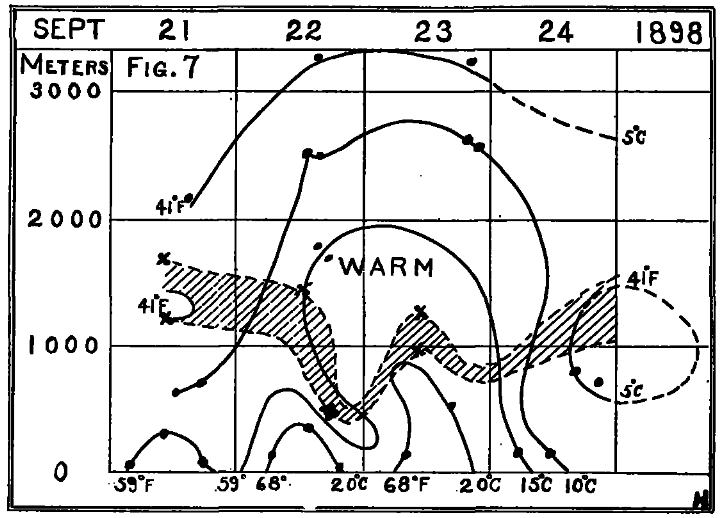


FIG. 7.—Vertical distribution of temperatures during September 21, 22, 23, 24, 1898, at Blue Hill, Mass.

In fig. 7 the diurnal rise in a belt of inverted gradient due to its being pushed upward by ascending currents from the heated ground is well shown on September 23. In such a case the belt rises to a maximum altitude during the afternoon and sinks again at night. This usually happens whenever the belt is within a thousand meters of the earth's surface. This diurnal rise interrupts and to some extent reverses the regular variation in height which takes place during the passage of warm and cold waves. All the apparent exceptions to the dipping of the belts toward regions of warmth are traceable to this diurnal period.

When the belt of inverted gradient is very near the ground, as in fig. 8, the ascending currents from the heated ground break through the belt and ascend to higher levels. When the belt is broken up in this manner during the day it strangely reappears at about the same height toward evening.

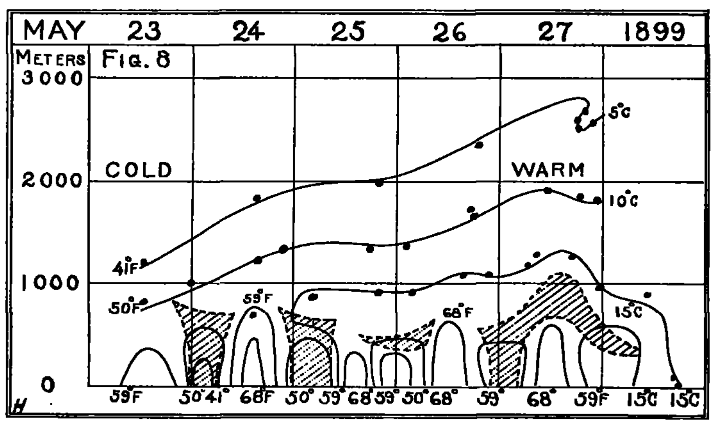


FIG. 8.—Vertical distribution of temperatures, May 23–27, 1899, at Blue Hill, Mass.

Since the air beneath a rising inverted gradient is colder than the air previously existing at the same level, the diurnal rise in the inverted gradient produces some curious anomalies in the diurnal period in the free air. For example, on September 23, 1898 (fig. 7) and May 27, 1899 (fig. 8) the temperature at 1,000 meters was lower in the afternoon than in the morning and evening of the same days. In other words, the ordinary daily change in temperature observed at the ground was reversed.

Occasionally a rapidly ascending body of air, on account of

its momentum and inertia, will rise through the belt of inverted gradient and form a temporary cloud of the cumulus or fracto-cumulus type at a level somewhat above the general level of the belt. In such cases the air in the cloud is colder than the air on either side of it, and it may be some 10° to 20° F. colder.

AN ANNOTATED BIBLIOGRAPHY OF EVAPORATION.

By MRS. GRACE J. LIVINGSTON. Dated Washington, D. C., January 8, 1908.

[*Continued from the Monthly Weather Review, April, 1909.*]

1897—*Continued.*

Fortier, Samuel.
Seepage water of northern Utah. Water sup. and irr. papers, 1897, No. 7: 17-24, 26, 43.

The apparatus consisted of a galvanized iron pan 36 by 36 by 10 inches floated in the reservoir. A diagonal bar scale permitted readings of the level to 1/100 inch. Tables of the evaporation at Fort Douglas, near Salt Lake City, Utah, for 1889-93, and at Fort Collins, Colo., 1887-91, are presented together with Russell's (1888) table of evaporation from the Piche atmometer at various localities in the United States. The total annual evaporation from water surfaces in Utah is estimated as from 3 to 6 feet, the evaporation during the dry season (May-August) of this region being equal to that of the other eight months. Gives a table of the relation between the crop harvested and the amount of evaporation. Under Logan river is discussed the relation between the rainfall and evaporation.

Houdaille, F.
Causes de vitesse maxima d'évaporation sous le climat de Montpellier. Ann. école nat. agr., Montpellier, 1897, **9**:286-95. Notice in Exp. sta. rec., 1897, **9**:1032-3.

The ratio of evaporation from the instrument previously described (Houdaille, 1890) to that from the Piche is given as 1.32. The mean daily evaporation (1875-84) varies between 2.28 millimeters in January and 9.35 millimeters in July. Gives the diurnal evaporation, temperature, humidity, and wind for January to September, 1896. Concludes that the wind is not an important factor in that locality, temperature and humidity being the main factors influencing evaporation there.

Krebs, Wilhelm.
Das Messen der Verdunstungsenergie mit dem Doppelthermometer. Met. Zeits., 1897, **14**:273-6.

Derives a formula for calculating evaporation directly from the readings of the psychrometer. Both Krebs and Ule (1897), claim priority in devising this method.

Latham, B.
Tables of evaporation from a 12-inch floating tank and a 5-inch exposed tank at Croydon, 1888-1897. Brit. rainf., 1897, (—):30-34.

Also gives illustration of Latham's evaporometer.

Madrid, Observatorio de.
Treinta años de observaciones meteorologicas, Madrid. 1860-94. Madrid. 1897.

Tables of the mean daily evaporation, 1860-94, from an exposed dish of water, accompanied by a table showing the lowering of temperature caused by evaporation. The average daily evaporation varies from 1.0 millimeter in January to 9.8 millimeters in July. The cooling effect varies from 1.3° C. to 9.1° C. for the same months. No yearly totals are given.

Pallich, J. von.
Ueber Verdunstung aus einer offen kreisförmigen Becken. Sitzber. k. Akad. Wiss. (Vienna), math. naturw. Kl., 1897, **107**(pt. 2a): 384-410.

Concludes that the ellipsoidal surfaces of equal vapor pressure above an evaporating surface, as mathematically derived by Stefan (1881), have too small an excentricity as compared with curves experimentally derived, and that this difference becomes more pronounced with higher temperatures. In the case studied this eccentricity should be 95 instead of 51 as given by Stefan's equation.

Royal Meteorological Society.
Exhibition of meteorological instruments in use in 1837 and 1897. Quart. jour. roy. met. soc., 1897, **23**:221-36.

On page 234 Pickering's (1898) atmometer is described; also a new Richard self-recording evaporometer. In this new pattern a sheet of blotting paper is kept moist by a wick which draws water from a closed reservoir. A float transmits to the pen the height of the liquid in the reservoir.

Rafter, Geo. W.
Stream flow in relation to forests. American Forestry Association, 1897, 12. Reprinted in Ann. rpt. Fisheries, Game, and Forest Commission for 1896. 1898.

An extensive discussion of the persistence at about the same rate, of the amount of evaporation from any given stream through long periods of time.

Symons, G. J. and H. Sowerby Wallis.
Records of evaporation. Brit. rainf., 1897, (—):28-34.

Gives the evaporation during 1897 at the usual stations, and also Latham's tables for 1888-97.

Ule, Willi.
Messung der Verdunstungsenergie mit dem Doppelthermometer. Met. Zeits., 1897, **14**:382-3.

Claims priority in the employment of the psychrometer to indicate the evaporating power of the air. (See Abbe, 1888, Krebs, 1895, 1897, and Ule, 1891.)

1898.

Abbe, Cleveland.
Evaporation and temperature. Mo. weather rev., 1898, **26**:213-4.

Summary of the work of Carpenter, 1898.

Bedford, Duke of.
See Pickering, S. U., and the Duke of Bedford.

Carpenter, L. C.
The loss of water from reservoirs by seepage and evaporation. Colorado Exp. sta. bul., 1898, No. 45. Abstract in Mo. weather rev., 1898, **26**:213. Abridged in Symons's met. mag., 1898, **33**:116-9.

Evaporation at Fort Collins, Colo., (alt. 4,990 ft.) from 1882-97, as measured by means of a hook-gage, gave an annual average of 40.94 inches. General discussion of the factors influencing evaporation. Unless the temperature of the water surface is warmer than the dew-point, evaporation can not proceed and condensation may occur. Evaporation from ice was 1.0 to 1.5 inches per month. The nocturnal evaporation, contrary to the general opinion, was almost the same as the diurnal, and these amounts approach equality as the body of water increases in size. Tabulates observations at many localities and altitudes in Colorado and California. He finds that the factors tending to decrease evaporation at high altitudes are lower temperatures, smaller differences between the vapor pressure at water surface temperature and that at the dew-point, and the decreased capacity for moisture of air at lower temperatures. Concludes that, although lessened air pressure and probable increased velocity of the wind at high altitudes favor evaporation, the annual rate is much less than at low altitudes.

Carpenter, L. C.
Losses of evaporation from canals. Records kept for two years on stretches of canals for irrigation purposes. Colo. Exp. sta. bul., 1898, No. 48. Summary in Exp. sta. rec., 1899, **10**:795-6.

Evaporation from canals is believed to be insignificant as compared with seepage, while in the case of reservoirs evaporation is the more important source of loss. The total depth of water lost from canals in the prevailing Colorado soils is estimated at from 1 to 2 feet per day over the whole surface of the canal, being less in clay soils than in sand or gravel.

Carpenter, L. C., and others.
Evaporation at the Colorado station. Colo. Exp. sta. bul., 1898, No. 49. Abstract in Exp. sta. rec., 1899, **10**:1019.

Results similar to those published in first title; repeats his formula published in 1888.

Gravelius, H.
Berichte über den Stand der Niederschlagsforschungen. Zeits. Gewässerk., 1898, **1**:341.

Reviews Heinz, 1898, who compared evaporation as observed at 15 stations in European Russia from 1871-95. A rapid increase in the annual evaporation is indicated in the direction from northwest to southeast: St. Petersburg, 331 millimeters; Vishni Volotshek, 352 millimeters; Moscow, 434 millimeters; Skopin, 572 millimeters; Nikolaiev (Saratof), 643 millimeters; Astrakhan, 750 millimeters. The yearly maximum occurred nearly everywhere in July and the minimum in January. Relations between the rainfall and evaporation are pointed out. Attention is drawn to the fact that experiments with evaporation from a grass surface have been conducted at Pavlovsk by means of Rykachev's (1900) atmometer since 1896.

Grunsky, Carl Ewald.
Irrigation near Fresno, Cal. Water sup. and irr. papers, 1898, No. 18:74-8.

Finds the loss of water from canals is less by evaporation than by seepage.

Heinz, E. A.
Ueber Niederschläge, Schneemenge, und Verdunstung in der Flussgebieten des Europäischen Russland. St. Petersburg. 1898. Review in Selsk. Khoz. i Lyesov., 1898, **109**:716-7. Notices in Met. Zeits., 1898, **15**:(77); Exp. sta. rec., 1898, **10**:327

Reviewed by Gravelius, 1898.

Héjas, André.
A zivatarok magyavországon az 1871 töl 1895—ig terjedö megfigyelések Alapján. (Die Gewitter in Ungarn nach den Beobachtungen von den Jahren 1871-95.—Kurzer Auszug des ungarischen Originales.) Budapest. 1898.

The original gives, on p. 50-1, the daily evaporation during March to October, for the years 1890-5, at Budapest. The average daily rate varied between 1.20 millimeters for March and 3.92 millimeters for July.

Maxwell, W.
Evaporation and plant transpiration. Jour. Amer. chem. soc., 1898, **20**:469-83. Reviewed in Exp. sta. rec., 1899, **10**:721-2.

Experiments were conducted at the experiment station at Honolulu, T. H., on the amount of moisture directly evaporated from the soil, and the relative proportion that escapes by transpiration from sugar cane during the different periods of growth. The transpiration from sugar cane growing in a tub was observed for 270 days, together with the outdoor and indoor evaporation of water in small galvanized evaporators, temperature, humidity, direction of wind, etc. The amount evaporated outdoors during this time was 33.480 cubic centimeters, with an average temperature of 75.9° F.; that indoors was only 14.175 cubic centimeters, with a temperature of 79.9° F. The humidity was the same in both cases. The inference is that the wind exerts a greater effect upon the rate of evaporation than the temperature.

Mazelle, E.
Verdunstung des Meerwassers und Süsswassers. Sitsber. k. Akad. Wiss. (Vienna), math.-naturw. Kl., 1898, **107**:(pt. 2). Also reprinted Vienna, 1898. 20p. 8vo. Abstracts in Ciel et terre, 1899, **20**:267-8; Anz. k. Akad. Wiss. (Vienna), math. naturw. Kl., 1898, no. 7, **35**:49-50.

Daily observations from June 1, 1896, to September 30, 1897, at Triest, with two Wild atmometers of similar construction and exposure, one containing fresh water, the other a 3.73 per cent salt solution, showed that the ratio between the results approached nearer unity as the rate of evaporation from the fresh water increased. An equation in which x is the evaporation from the fresh water, and y that from the salt water, shows the following relation: $y = -0.018 + 0.7303x + 0.0561x^2 - 0.0044x^3$. The total amount evaporated from the fresh water was 910.6 millimeters, that from the salt water 750.9 millimeters, the ratio being 100:82.46. Complete tables compare these rates of evaporation with other meteorological factors.

Mohn, H[enryk].
Grundzüge der Meteorologie. Berlin. 1898. (5th ed.)

See Mohn, 1875.